COMMONWEALTH OF VIRGINIA
STATE IMPLEMENTATION PLAN REVISION

TECHNICAL SUPPORT DOCUMENTATION FOR
OPACITY VARIANCE FOR ROCKET TEST FACILITY
at
Aerojet Corporation
Orange County Facility
7499 Pine Stake Road
Culpeper, Virginia 22701
Registration No. 40743

On September 30, 2002, the State Air Pollution Control Board adopted an opacity variance (9 VAC 5 Chapter 220) for the rocket motor test operations at Atlantic Research Corporation's Orange County facility from the standard for visible emissions in 9 VAC 5-50-80. In lieu of compliance with this standard, the variance required the facility to limit total particulate matter emissions from its rocket motor test operations to 714 pounds per hour. Subsequently, the facility was purchased by Aerojet Corporation. This variance was submitted to the U.S. Environmental Protection Agency (EPA) as a revision to the Virginia state implementation plan (SIP) on January 26, 2004.

The January 2004 SIP submittal contained a technical support document (TSD) that provided a basis for proposed hourly limit for particulate matter emissions from the rocket motor testing operations. In conducting its administrative and technical review of the submittal, EPA determined that the technical support document did not provide adequate air dispersion modeling information. On April 20, 2005, the company provided a more comprehensive TSD, "Technical Support Documentation for Opacity Variance for Rocket Test Facility," which is attached.

This TSD was reviewed by EPA, which provided a number of questions and comments. One of the comments was that the OB/OD Model software program used to estimate the PM emissions from the rocket motor testing operations was is not an EPA-approved model.

On May 5, 2008, the Department of Environmental Quality requested EPA approval of an alternative air quality model for analyzing air quality in support of the variance. EPA approved this request on July 24, 2008; a copy is attached.

On August 29, 2008, the company provided responses to the remaining EPA comments, which is attached.

These documents provide the information necessary for EPA to complete its review and the SIP approval process. The documents have been reviewed by the Department of Environmental Quality; the department agrees with the company's modeling procedures and results.

The TSD includes references to the PM_{10} annual NAAQS. All references to the annual

PM_{10} NAAQS should be disregarded due to the fact that EPA revoked this standard on December 18, 2006.

The Aerojet modeling analysis demonstrates that emissions from the facility do not cause or contribute to a violation of the 24-hour PM_{10} NAAQS. The modeling of PM_{10} was used as a surrogate for demonstrating compliance with the $PM_{2.5}$ NAAQS pursuant to the DEQ and EPA surrogate policies outlined in Air Guidance Memo No. APG-307 *("Interim Implementation of New Source Review for* $PM_{2.5}$*"*, October 12, 2006). Specifically, a compliance demonstration with the PM_{10} NAAQS represents a compliance demonstration with the $PM_{2.5}$ NAAQS. It is also important to note that annual PM_{10} impacts were below EPA's significant impact levels at all offsite locations.

Lastly, Aerojet is located in Orange County, Virginia, which is designated as attainment with respect to the annual and 24-hour $PM_{2.5}$ NAAQS. Emissions from this facility are not expected to cause or significantly contribute to a violation of the $PM_{2.5}$ NAAQS locally or regionally. The nearest nonattainment area (Washington, D.C. metropolitan statistical area) is located approximately 50 miles northeast of Aerojet, and impacts from the facility's emissions at a downwind distance of 50 miles are expected to be insignificant.

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AIR DISPERSION MODELING INFORMATION

TECHNICAL SUPPORT DOCUMENTATION FOR OPACITY VARIANCE FOR ROCKET TEST FACILITY

Aerojet Corporation
Orange County Facility
7499 Pine Stake Road
Culpeper, Virginia 22701
Registration No. 40743

Submitted To:

Virginia Department of Environmental Quality
629 East Main Street
Richmond, Virginia 23219

Date of Submittal:

April 20, 2005

7499 Pine Stake Road
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Inventory of Enclosed Documents

Technical documentation provided by Aerojet on April 20, 2005 in support of the Opacity Variance for the rocket motor test operations at the Orange County facility are listed below and are available in electronic form:

(1). OB/OD Modeling Study dated March 1999

- 1.1 Modeling Protocol and Discussion of Results
- 1.2 Site Map of Orange County Facility
- 1.3 Output Files for OB/OD Modeling Runs for Particulate Matter (PM10) for Calendar Years 1987 Through 1991

(2). Revised OB/OD Modeling Study dated June 2002

- 2.1 Modeling Protocol and Discussion of Results
- 2.2 Site Map of Orange County Facility
- 2.3 Output Files for OB/OD Modeling Runs for Particulate Matter (PM10) for Calendar Years 1987 Through 1991
- 2.4 Output Files for OB/OD Modeling Runs for Particulate Matter (PM100) for Calendar Years 1987 Through 1991
- 2.5 Output Files for OB/OD Modeling Runs for Particulate Matter (PM1000) for Calendar Years 1987 Through 1991
- 2.6 Input and Output OB/OD Files for All PM Modeling Runs Conducted in 2002 (Four Files Per Run)

(3). Meteorological Data Files for Dulles Airport for Calendar Years 1987 through 1991

(4). OB/OD Modeling Software and Associated Information

- 4.1 Current Version of OB/OD Modeling Software (Version 1.3.0021 Dated January 2005) [earlier versions of program were used for 1999 and 2002 modeling studies]
- 4.2 User's Guide for OB/OD Model (Two Volumes)

Open Burn/Open Detonation Emissions Modeling Protocol and Discussion of Results for Emissions of Particulate Matter from Rocket Motor Testing Operations

Atlantic Research Corporation - Orange County, Virginia

March 1999

Atlantic Research Corporation (ARC) operates an industrial facility located near the city of Culpeper in Orange County, Virginia. The company produces solid rocket motors for the United States Department of Defense. The propellants for these units are also manufactured on-site. Certain motors are performance tested for quality control or research and development purposes. The rocket motors are fired in a specially constructed Rocket Test Facility (RTF).

At ARC's request, Engineering, Compliance & Construction, Inc. (ECCI) performed dispersion modeling of the air emissions generated at the RTF. The modeling was performed using the Open Burn/Open Detonation (OB/OD) software program developed by the United States Army at the Dugway Proving Grounds in Dugway, Utah. The OB/OD model is the most appropriate software program currently available for predicting the air quality effects of open burn events such as the rocket testing operations conducted at ARC's Orange County facility. The program is particularly well suited for modeling short-term combustion events (i.e., less than ten minutes in duration). The OB/OD model has been accepted for use by the state of Utah and Region VIII of the Environmental Protection Agency (EPA). (A list of regulatory contacts that are familiar with the air model is included as Attachment A.)

The OB/OD modeling was conducted, in part, to demonstrate that the emissions of particulate matter (PM) from the RTF do not cause or contribute to a violation of the National Ambient Air Quality Standards (NAAQS) for that pollutant.

The OB/OD modeling protocol and results for the PM emissions from the rocket motor test operations are presented in this document. The protocol describes the technical approach and parameters that were utilized when performing the computer simulations for the RTF. The criteria for evaluation of the PM modeling data are also discussed. Finally, the results of the OB/OD modeling exercise for the RTF are summarized herein. The data demonstrate that the predicted maximum ground-level ambient air concentrations of PM are well below the NAAQS at all receptors (whether located on-site or off-site).

1.0. GENERAL FACILITY INFORMATION

General information on the rocket testing operations at the ARC facility in Orange County, Virginia is provided in the following paragraphs.

1.1 **Rocket Testing Operations**: ARC tests several types of solid rocket motors at the Orange County facility. The propellant weight in the motors can range from 35 pounds to 2,000 pounds. Several different rocket fuels are processed on-site.

A certain percentage of the solid rocket motors are performance tested by ARC for quality control or research and development purposes. The RTF has been specially designed and constructed for this purpose. The site consists of two covered test bays situated within a bermed open-air area. The RTF also includes a remote control/monitoring station. (The test site is located at the approximate center of the overall ARC facility. See the attached plot plan (Figure 1) for the location of the rocket test site.)

To prepare for a test, the rocket motor is transported from storage to the RTF. The unit is then securely mounted on a test stand. Instrumentation is subsequently attached to the rocket motor assembly. (The motor case may be subjected to temperature conditioning prior to testing. The motors are fired in a horizontal position.)

When preparations are complete, the rocket motor is electronically fired from the remote control station. The firing conditions and operating parameters are monitored and recorded during the test. An individual test event ranges from approximately 30 seconds to ten minutes in duration depending on the size of the motor and the test conditions. The combustion by-products generated during the event are released directly to the atmosphere. A maximum of 2,000 pounds of rocket propellant can be fired per test (although a motor that large has never been tested at the facility to date).

After firing, the spent motor case is removed from the test bay. Depending on the engineering requirements, the case may be disassembled and inspected. Other spent rocket motor units may be recycled or simply decontaminated for off-site disposal.

1.2 **Propellant Formulations**: ARC manufactures and/or processes several different types of solid rocket propellants at the Orange County facility. These fuels predominantly consist of aluminum/ammonium perchlorate-based propellants and "HMX" -based propellants. (HMX is an abbreviation used for the energetic compound cyclotetramethylene-tetranitramine.)

Additional solid rocket propellants were considered during the OB/OD modeling exercise in order to provide for future operational flexibility at the Orange County facility. These materials consisted of solid fuels currently manufactured and/or processed at other ARC facilities.

1.3 **Propellant Emission Factors**: The U.S. Department of Defense (DOD) has developed a computer software program that predicts the exhaust species generated during the combustion of solid rocket propellants under various conditions. ARC used this program to calculate the theoretical products of combustion for a variety of common propellants.

For the rocket testing operations, a low fuel-to-air ratio was utilized in the computer program to simulate low oxygen conditions during propellant combustion within the rocket motor case.

A set of worst-case "super rocket propellant" emission factors was subsequently developed for the RTF. First, the maximum concentrations of more than 30 different pollutant species were estimated for each rocket fuel studied. This data was expressed as the normalized weight percentage of each pollutant generated per unit of propellant combusted (i.e., pounds of pollutant emitted per 100 pounds of rocket fuel fired). The set of "super rocket propellant" factors was then obtained by selecting the highest weight percentage emitted of each pollutant for any of the propellants studied. This approach maximized the ambient air concentrations of PM predicted by the OB/OD model for the RTF. The PM emission factor utilized during the modeling exercise is presented in Table 1.

1.4 **Modeling of PM Emissions**: PM is emitted during the rocket testing operations at the Orange County facility. For the purposes of the OB/OD modeling exercise, the emissions of total PM were evaluated as aluminum oxide (Al_2O_3), since physical constants are not available for PM and Al_2O_3 is one of the predominant particulate species generated. The emission factor for total PM was utilized in combination with the molecular weight and density values for Al_2O_3.

When modeling PM, a median aerodynamic diameter of 10 micrometers (10 um) was used in order to maximize the predicted ambient air concentrations. The OB/OD model automatically calculated the particle-size distribution over 20 size categories. (The gravitational deposition of the particulate emissions was not evaluated.)

The physical characteristics utilized during the OB/OD modeling study are provided in Table 1.

1.5 **Description of Emission Source**: OB/OD modeling runs were performed for the RTF. The operating characteristics utilized for this source were as follows: The effects of only one rocket test event per day were evaluated. The maximum amount of solid rocket fuel fired per event was 2,000 pounds. A test duration of three minutes was utilized for modeling purposes. (These source characteristics reflect the anticipated maximum operating conditions at the Orange County facility.)

2.0 OB/OD MODELING PROTOCOL

The protocol for the OB/OD modeling exercise for ARC's Orange County facility is provided in following paragraphs. The protocol describes the technical approach and parameters that were utilized when performing the computer simulations for the RTF. The criteria for evaluation of the modeling data are also discussed herein.

2.1 **Description of OB/OD Modeling Software**: The ambient air dispersion modeling analysis for ARC was performed using the OB/OD computer software program (version 1.3.0012 dated January 1999). The U.S. Army developed this program at the Dugway Proving Grounds in Dugway, Utah. A private contractor, the H.E. Cramer Company of Sandy, Utah, was instrumental in development of the software. (The primary contact for the OB/OD model is Mr. Jay Bjorklund of the H.E. Cramer Company. A list of regulatory contacts that are familiar with the modeling software is provided herein as Attachment A.)

The OB/OD model is designed for use in evaluating the potential air quality impacts of the open-air burning and detonation of obsolete munitions and solid propellants at DOD installations and similar facilities. The model can be run using either theoretical or empirical emission factors for various pollutants in either gaseous or particulate form. The software predicts the downwind transport and dispersion of these pollutants using cloud rise and dispersion model algorithms from existing EPA computer programs. The model can be used to consider both instantaneous (i.e., detonation) and "quasi-continuous" (open burning/firing) releases from point/volume and/or line sources. The OB/OD software program can be used to calculate time-mean concentration, dosage and particulate gravitational deposition from open burn and open detonation sources.

2.2 **Source Characteristics**: The OB/OD model was programmed to reflect actual operations at the RTF under maximum or worst-case conditions. The operating characteristics for this source are summarized below:

2.2.1 **Type of Emission Source**: The RTF was modeled as a "quasi-continuous" source to reflect the actual rocket testing operations (i.e., open burning/firing). The effects of a three-minute test event at the maximum propellant weight of 2,000 pounds were evaluated. (The alternative modeling approach, for an "instantaneous" source, is appropriate for detonation events. These events normally last less than 15 seconds. Detonation events are not conducted at the Orange County facility.)

In addition, the RTF was modeled as a "volume" (i.e., point) source (as opposed to a "line" source). The OB/OD model was programmed to use default settings for the dimensions of the initial source material (i.e., 10 meters by 10 meters by 10 meters). A default setting was also utilized for the effective height of the initial release above ground level. A value of five meters was used (one-half of the initial depth of the material).

(The aforementioned settings were programmed with the direct assistance of the designer of the OB/OD software. These default values should accurately reflect actual operating conditions at the ARC facility. According to Mr. Bjorklund, the dimensional settings reflect the volume of the initial release (i.e., exhaust plume/fireball), rather than the physical size of the rocket motor being tested. One test run was performed to determine the effects of the dimensions of the initial source material and the initial release height at the RTF on the predicted air emissions. The dimensions of the source were programmed at 10 meters by 10 meters by two meters. In addition, a value of two meters was used for the effective height of the initial release above ground level. The predicted ambient air concentrations under these circumstances were not significantly different from those values resulting from the default settings described above.)

2.2.2 **Characteristics of Rocket Test Event**: The OB/OD model was programmed to simulate the firing of 2,000 pounds of solid rocket propellant per event. The effects of only one test event per day were evaluated. For modeling purposes, it was assumed that the rocket motor would fire for a three-minute period before all the fuel is consumed. The time of the test event was arbitrarily set at 12:00 noon. (These source characteristics reflect the anticipated maximum operating conditions at the RTF. More than one rocket test event may be performed per day, but the aggregate weight of propellant fired will not exceed 2,000 pounds. Similarly, the tests may range from 30 seconds to ten minutes in duration, depending on the size of the rocket motor and/or the physical test conditions. A three-minute burn is the maximum test duration anticipated at the maximum test weight of 2,000 pounds.)

(Two test runs were performed to determine the effects of the time of the rocket test event on the predicted air emissions. Morning and afternoon events (9:00 A.M. and 3:00 P.M., respectively) at the RTF were evaluated. The predicted ambient air concentrations of PM under these circumstances were not significantly different from those values resulting from a rocket test event occurring at 12:00 noon.)

2.2.3 **PM Emission Factor**: The "super rocket propellant" emission factor for PM was utilized when conducting the OB/OD modeling runs for the RTF. This value is presented in Table 1. (This theoretical emission factor was calculated using the DOD's products of combustion software program. See Section 1.3 above for a brief discussion of the methodology used to develop this information.)

2.2.4 **Characteristics of Rocket Propellants Tested**: A burn rate of 5,044 grams per second was used for modeling purposes at the RTF. This value reflects the maximum test duration (three minutes) anticipated at the maximum test weight (2,000 pounds). A default setting of 1,000 calories per gram was utilized for the heat content of the solid rocket fuel. (The OB/OD model contains a database of common propellants and explosives and their thermodynamic characteristics.)

2.3 **Receptor Grid**: A rectangular (Cartesian) receptor grid was utilized for the OB/OD modeling exercise. The RTF was established at the point of origin (0.0, 0.0) for the grid network. The receptors were placed at 100-meter intervals from the source. The east-west (X) axis extended from -3,000 meters to 3,000 meters. The north-south (Y) axis also ranged from -3,000 meters to 3,000 meters. Flat terrain settings with ground level receptors were utilized to reflect actual on-site conditions and points of exposure.

Maximum PM concentrations were specifically determined at the property boundary location closest to the RTF. This particular receptor is situated south-southeast of the test site at coordinates -1,200 meters north, -200 meters east. (The closest property boundary, on State Highway 602, is actually located at -1,218.8 meters north, -177.7 meters east. See Figure 1 (Site Map) for details.)

2.4 **Meteorological Data**: The meteorological data used in conjunction with the OB/OD model consisted of hourly, joint-frequency distributions of wind direction, wind speed, temperature and Pasquill atmospheric stability classes arranged in chronological order. Per the instructions of the VDEQ, the set of meteorological information used for the ARC modeling exercise consisted of the most recent five years of data available (i.e., calendar years 1987 through 1991) for Dulles Airport near the city of Herndon (Loudoun County), Virginia. (The aforementioned frequency distributions are commonly referred to as "STAR" (stability array) data. The meteorological data for Dulles Airport were provided by the VDEQ.)

Default values were utilized for all other meteorological variables in the OB/OD model. These settings included the following:

- Mixing Layer Depth = 200 meters
- Air Humidity = 50 percent
- Air Pressure = 870 millibars
- Vertical Potential Temperature Gradient = 0.01 centimeters per second

The OB/OD model did not include calm hours (i.e., no wind) in the dispersion calculations.

2.5 **Time-Averaging Periods**: The OB/OD software program can be used to calculate time-mean concentration, dosage and other emission values. The NAAQS for PM are based on 24-hour and annual time-averaging periods. During the OB/OD modeling exercise for the Orange County facility, the ground-level ambient air concentrations of PM were accordingly computed for these periods.

The NAAQS and time-averaging periods applicable to PM are described in Table 2.

2.6 **Criteria for Evaluation of PM Emissions**: As stated previously, the OB/OD modeling exercise was conducted, in part, to determine whether the PM emissions from the RTF would cause or contribute to a violation of the NAAQS for that pollutant. The NAAQS are specified in 40 Code of Federal Regulations, Part 50. The PM standards are based on 24-hour and annual time-averaging periods. (See Table 2.) The predicted ambient air concentrations of PM from the RTF must be below the NAAQS in order to comply with federal air quality regulations.

The 50 highest ambient air PM concentrations were determined for both the 24-hour and annual time-averaging periods. These maximum values might occur at either on-site or off-site receptors depending on meteorological effects. In addition, the maximum PM concentration at the nearest property boundary was also determined for each time-averaging period.

3.0 RESULTS OF OB/OD MODELING STUDY

The results of the OB/OD modeling exercise for the rocket testing operations at the ARC facility in Orange County, Virginia are summarized in the following paragraphs. The data demonstrate that the predicted maximum ground-level ambient air concentrations of PM_{10} will be below the NAAQS at all receptors (whether located on-site or off-site). The modeling results for the RTF are presented in Table 3. The concentrations are reported in units of micrograms per cubic meter (ug/m3). For the five-year period of meteorological data used (1987 through 1991), the maximum PM concentrations at the RTF occurred during calendar year 1990.

3.1 **Results of Modeling for Total Particulate Matter (as PM_{10})**: According to the OB/OD model, the maximum ambient air concentrations of total particulate matter (as PM_{10}) generated by the RTF operations will be well below the applicable two NAAQS thresholds. The predicted ground-level concentrations and regulatory standards are as follows:

- The predicted 24-hour concentration of PM_{10} is 8.75 ug/m3, which is less than the applicable NAAQS threshold of 150 ug/m3.

- The predicted annual concentration of PM_{10} is 0.57 ug/m3, which is less than the applicable NAAQS threshold of 50 ug/m3.

4.0 CONCLUSION OF PM MODELING

In conclusion, the predicted maximum ground-level ambient air concentrations of PM_{10} from the RTF operations will be below the NAAQS at all receptors (whether on-site or off-site).

Summaries of the OB/OD modeling results for PM are attached for reference purposes. Graphic isopleth displays of the predicted ambient air concentrations over certain time-averaging periods at the RTF are also enclosed herein. (Upon request, ARC will provide the VDEQ with a copy of the OB/OD modeling software package and computer diskettes containing all of the modeling data generated during this project.)

Table 1 - Physical Characteristics and Emission Factor for PM

Pollutant	Type of Pollutant	Molecular Weight (grams/mole)	Density (grams/cubic centimeter)	Emission Factor [A]
Particulate Matter, Total (as PM_{10}) [B, C]	Particulate	101.9	3.99	35.70

(A). Worst-case "super rocket propellant" emission factors were developed for several common solid rocket fuels processed at ARC facilities. Theoretical emission factors were obtained using the products of combustion model developed by the U.S. Department of Defense. ARC provided the data. Emission factors are expressed as pounds of pollutant released per 100 pounds of propellant fired (pounds/100 pounds) during performance testing of solid rocket motors.

(B). All modeling runs at Rocket Test Facility (RTF) were performed using the following source characteristics: 2,000 pounds of solid rocket propellant fired per event; one test event performed per day at 12:00 noon; rocket firing occurs over a three-minute period; heat content of propellant is 1,000 calories per gram; and burn rate of rocket fuel is 5,044 grams per second.

(C). Emissions of total particulate matter (PM) were evaluated as aluminum oxide (Al_2O_3) since molecular weight and density values are not available for PM. OB/OD emission factor for total PM was used in combination with the physical constants for Al_2O_3. (Al_2O_3 is one of the predominant particulate species generated during the rocket testing events.)

Predicted ambient air concentrations of PM were maximized by assuming that the particles have a median aerodynamic diameter of 10 micrometers (10 um). OB/OD model automatically calculated the particle-size distribution over 20 size categories.

Table 2 - Time-Averaging Periods and Air Quality Standards

Pollutant	NAAQS (ug/m3)	
	24-Hour	Annual
Particulate Matter, Total (as PM_{10}) (A, B)	150	50

(A). Regulatory criteria for this pollutant are the National Ambient Air Quality Standards (NAAQS). These federal standards were established by the Environmental Protection Agency. Concentrations are reported in units of micrograms per cubic meter (ug/m3).

Two sets of NAAQS are applicable to total particulate matter. The standards are based on the median aerodynamic diameter of the particle size ranges. The NAAQS for PM with a mean diameter of 10 micrometers (um) (PM_{10}) are 150 ug/m3 (24-hour average) and 50 ug/m3 (annual arithmetic mean).

(B). Emissions of total particulate matter (PM) were evaluated as aluminum oxide (Al_2O_3) since molecular weight and density values are not available for PM. OB/OD emission factor for total PM was used in combination with the physical constants for Al_2O_3. (Al_2O_3 is one of the predominant particulate species generated during the rocket testing events.)

Predicted ambient air concentrations of PM were maximized by assuming that the particles have a median aerodynamic diameter of 10 um. OB/OD model automatically calculated the particle-size distribution over 20 size categories.

Table 3 - OB/OD Modeling Results for PM Emissions from Rocket Test Facility

Pollutant	Averaging Period	Maximum Predicted Concentration (ug/m3) (A)	NAAQS (ug/m3)	Pass or Fail	Concentration at Property Boundary (ug/m3) (D)
Particulate Matter, Total (as PM_{10}) (B, C)	24 hours	8.75	150 (as PM_{10})	Pass	3.56
	Annual	0.57	50 (as PM_{10})	Pass	0.30

(A). Maximum ambient air concentration of particulate matter (PM) at ground level as predicted by the OB/OD dispersion model. Concentrations are reported in units of micrograms per cubic meter (ug/m3). Modeling was performed using meteorological data for Dulles Airport for calendar years 1987 through 1991. Maximum concentrations of PM at Rocket Test Facility (RTF) will occur during 1990.

All modeling runs at RTF were performed using the following source characteristics: 2,000 pounds of solid rocket propellant fired per event; one test event performed per day at 12:00 noon; rocket firing occurs over a three-minute period; heat content of propellant is 1,000 calories per gram; and burn rate of rocket fuel is 5,044 grams per second.

(B). Regulatory criteria for PM are the federal National Ambient Air Quality Standards (NAAQS). Two sets of criteria are applicable to total PM. The standards are based on the median aerodynamic diameter of the particle size ranges. The NAAQS for PM with a mean diameter of 10 micrometers (um) (PM_{10}) are 150 ug/m3 (24-hour average) and 50 ug/m3 (annual arithmetic mean).

(C). Emissions of total PM were evaluated as aluminum oxide (Al_2O_3) since molecular weight and density values are not available for PM. OB/OD emission factor for total PM was used in combination with the physical constants for Al_2O_3. (Al_2O_3 is one of the predominant particulate species generated during the rocket testing events.)

Predicted ambient air concentrations of PM were maximized by assuming that the particles have a median aerodynamic diameter of 10 um. OB/OD model automatically calculated the particle-size distribution over 20 size categories.

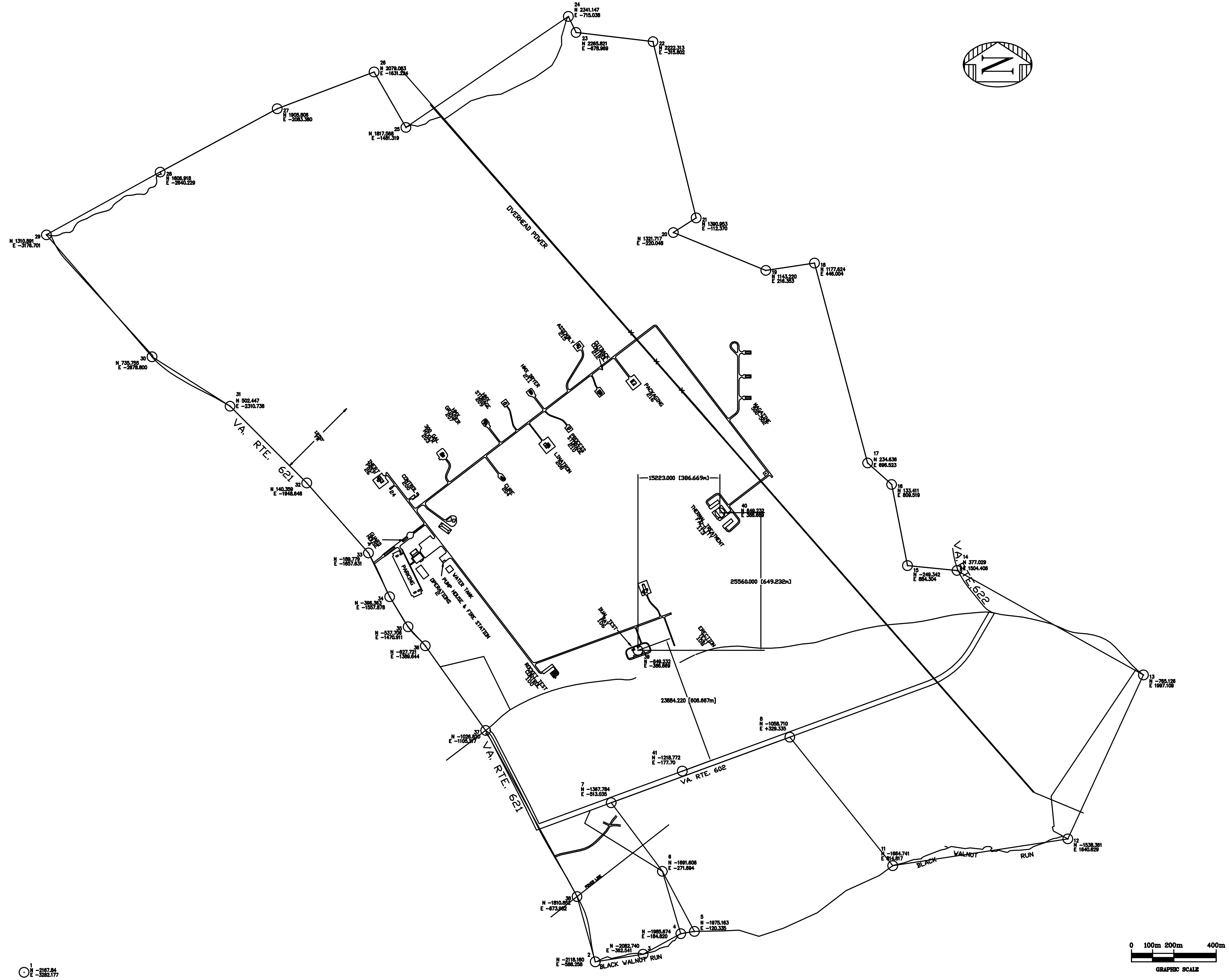
(D). Maximum concentration of each pollutant at nearest property boundary is reported. This receptor is situated south-southeast of the RTF at coordinates -1,200 meters north, -200 meters east. (RTF was established as point of origin (0.0, 0.0) for receptor grid when conducting modeling runs for test site. Closest property boundary, on State Highway 602, is actually located at -1,218.8 meters north, -177.7 meters east.)

Attachment A
List of Contacts for Information on OB/OD Modeling Software

Name	Affiliation	Telephone Number
Jay Bjorklund	H. E. Cramer Co. Sandy, Utah	(801) 561-4964
Jim Bowers, John White	U.S. Army Proving Grounds Dugway, Utah	(801) 831-5101
Jeff Weil	University of Colorado Denver, Colorado	(303) 497-8907
Terry Brown	EPA - Region VIII Denver, Colorado	(303) 312-6419
Linda Matyskiela	EPA - Region III Philadelphia, Pennsylvania	(215) 814-3420
Liz Bartlet	EPA - Region IV Atlanta, Georgia	(404) 562-4300

Figure 1

Site Map
Atlantic Research Corporation
Orange County Facility



Atlantic Research Corporation
a subsidiary of Sequa Corporation

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	DATE
DESIGNED BY: D.C.	8/98
DRAWN BY: G.C.G.	9/98
CHECKED BY: D.C.	9/98
APPROVED BY:	9/98

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☐ APPROVAL
☐ BID PURPOSES
☐ CONSTRUCTION

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ARC
PROPULSION DIVISION
Orange County Facility

a subsidiary of Sequa Corporation

FILE: ARC-VA1

ORANGE COUNTY FACILITY
GENERAL SITE PLAN

PROJECT NO.	SCALE	DRAWING NO.	REV.
3026-	AS NOTED	ARC-VA – 100-01-001	B

REVISED OPEN BURN/OPEN DETONATION EMISSIONS MODELING PROTOCOL AND DISCUSSION OF RESULTS FOR EMISSIONS OF PARTICULATE MATTER FROM ROCKET MOTOR TESTING OPERATIONS

ATLANTIC RESEARCH CORPORATION - ORANGE COUNTY, VIRGINIA

JUNE 2002

Atlantic Research Corporation (ARC) operates an industrial facility located near the town of Culpeper in Orange County, Virginia. The company produces solid rocket motors and rocket propellants for the United States Department of Defense. For quality control and research and development purposes, a percentage of the rocket motors are performance tested in a specially constructed Rocket Test Facility (RTF).

At ARC's request, Engineering, Compliance & Construction, Inc. (ECCI) performed dispersion modeling of the air emissions generated at the RTF. An initial round of modeling for the rocket test operations was completed in March 1999 (refer to Open Burn/Open Detonation Emissions Modeling Protocol and Discussion of Results, March 16, 1999, on file at VDEQ). A second round of modeling, which is the subject of this document, was completed in June 2002. It utilizes updated emission factors for air pollutants at the RTF.

The modeling study described herein was performed using the Open Burn/Open Detonation (OB/OD) software program (versions 1.3.0017 dated July 2000 and 1.3.0018 dated May 2001) developed by the United States Army at the Dugway Proving Grounds in Dugway, Utah. The OB/OD model is the most appropriate software program currently available for predicting the air quality effects of open burn events such as the rocket testing operations conducted at ARC's Orange County facility. The program is particularly well suited for modeling short-term combustion events (i.e., less than ten minutes in duration). The OB/OD model has been accepted for use by the state of Utah and EPA Region VIII.

The OB/OD modeling was conducted, in part, to demonstrate that the emissions of particulate matter (PM) from the RTF do not cause or contribute to a violation of the National Ambient Air Quality Standards (NAAQS) for that pollutant.

The revised OB/OD modeling protocol and results for the PM emissions from the rocket motor test operations are presented in this document. The protocol describes the technical approach and parameters that were utilized when performing the computer simulations for the RTF. The criteria for evaluation of the PM modeling data are also discussed. Finally, the results of the OB/OD modeling exercise for the RTF are summarized herein. The data demonstrate that the predicted maximum ground-level ambient air concentrations of PM are well below the NAAQS at all off-site receptors.

The modeling results described herein were generated using revised OB/OD emission factors for the RTF. ARC has developed new emission factors since the previous modeling study in 1999. The most recent factors reflect the processing of additional rocket propellants that are not currently treated or manufactured on-site, but may be in the future. These propellants were included in this study in order to provide future operational flexibility for ARC.

1.0. General Facility Information

General information on the rocket testing operations at the ARC facility in Orange County, Virginia is provided in the following paragraphs:

1.1 **Rocket Testing Facility**: ARC processes several types of solid rocket fuels and motors at the Orange County facility. The propellant weight in the motors can range from less than one pound to 2,000 pounds, depending on the component tested and the test stand used.

ARC tests a certain percentage of the solid rocket motors for quality control or research and development purposes. The RTF has been specially designed and constructed for this purpose. The site consists of two covered test bays situated within a bermed open-air area. The RTF also includes a remote control/monitoring station. (See the attached plot plan (Figure 1) for the location of the rocket test site.)

To prepare for a test, the rocket motor is transported from storage to the RTF. The unit is then securely mounted on a test stand. Instrumentation is subsequently attached to the rocket motor assembly. The motor case may be subjected to temperature conditioning prior to testing. The motors are fired in a horizontal position.

Once preparations are complete, the rocket motor is electronically fired from the remote control station. The firing conditions and operating parameters are monitored and recorded during the test. An individual test event ranges from several seconds to ten minutes in duration, depending on the size of the motor and the test conditions. The combustion by-products generated during the event are released directly to the atmosphere. A maximum of 2,000 pounds of rocket propellant can be fired per test.

After firing, the spent motor case is removed from the test bay. Depending on the engineering requirements, the case may be disassembled and inspected. Other spent rocket motor units may be recycled or simply decontaminated for off-site disposal.

The daily throughput of rocket propellants at the RTF is summarized below:

- A maximum of 2,000 pounds of propellant will be tested per day.
- Up to 2,000 pounds of total propellant will be tested per event.

ARC calculates the hourly emission rate for PM during each test event by multiplying the weight of propellant in the motor case being fired by the propellant-specific emission factor.

1.2 **Propellant Formulations**: ARC currently manufactures and/or processes several different types of solid rocket propellants at the Orange County facility. These fuels predominantly consist of aluminum/ammonium perchlorate-based propellants and "HMX" -based propellants. (HMX is an abbreviation used for the energetic compound cyclotetramethylene-tetranitramine.)

Additional solid rocket propellants were considered during the OB/OD modeling exercise in order to provide for future operational flexibility at the Orange County site. These materials consisted of solid fuels currently manufactured and/or processed at other ARC facilities, which may be handled at the Orange County facility in the near future.

1.3 **Propellant Emission Factors**: ARC makes and/or processes a number of solid rocket fuels and airbag propellants, the formulations for which change occasionally due to research and development advances. The company will also process additional propellants as new production programs are developed in the future. For these reasons, ARC utilized a generic worst-case propellant formulation when conducting the OB/OD modeling studies for the RTF. This approach offered two main advantages: (1) it would maximize the ambient air concentrations predicted by the OB/OD model and (2) it would provide maximum operational flexibility for the facility.

ARC uses a predictive computer thermochemical code known as "EQTCH" (Equilibrium Thermochemistry Computer Code) to determine the chemical composition and quantities of air emissions from rocket motor testing. The use of the thermochemical model is the only practical method to accurately estimate the predominant species of emissions from the test events. The EQTCH program was developed in cooperation with the U.S. Department of Defense (DOD) and validated through the efforts of numerous government agencies, including the Naval Weapons Center, the Joint Navy-NASA-Air Force Propulsion Committee, and the National

Bureau of Standards. EQTCH calculates chemical equilibrium in complex systems and determines combustion product composition, heat generation, and amount of gases and solids generated.

For each propellant to be modeled, the empirical formulas of the ingredients in the propellant are input into the EQTCH model. If appropriate, process aids (i.e., anti-static bags, rags, cardboard) and/or accelerants are also input into the EQTCH model in order to account for non-propellant materials. The output data is expressed as emission compositions and factors (mass of combustion byproduct per mass of propellant burned), and is typically presented as the normalized weight percent of each pollutant generated per unit of propellant (i.e. pounds of pollutant per 100 pounds of propellant fired). Emissions of the different combustion by-product species are predicted for the various types of propellants. The majority of the solid rocket propellants manufactured by ARC are aluminum-based, and the predominant combustion by-products are metal oxides and simple gases.

A set of worst-case rocket propellant emission factors was developed for the RTF in the following manner: First, the maximum concentrations of more than 30 different pollutant species were estimated for each rocket fuel studied. This data was expressed as the pounds of pollutant emitted per 100 pounds of rocket propellant tested. The set of worst-case rocket propellant factors was then obtained by selecting the highest weight percentage emitted of each pollutant for any of the propellants studied. This approach maximized the ambient air concentrations of PM predicted by the OB/OD model for the RTF.

The PM emission factor utilized during the modeling exercise is presented in Table 1.

1.4 **Modeling of PM Emissions:** PM is emitted during the rocket testing operations at the Orange County facility. For the purposes of the OB/OD modeling exercise, the emissions of total PM were evaluated as aluminum oxide (Al_2O_3), since physical constants are not available for total PM and Al_2O_3 is one of the predominant particulate species generated. The emission factor for total PM was utilized in combination with the molecular weight and density values for Al_2O_3.

The air emissions of total PM (as Al_2O_3) were modeled using three different median particle sizes (i.e., "aerodynamic diameters") in order to maximize the predicted air concentrations and gravitational deposition values. These sizes were 10 microns (10 um), 100 um, and 1,000 um. The OB/OD model automatically calculated the particle-size distribution for each median diameter over 20 size categories.

The physical characteristics utilized during the OB/OD modeling are provided in Table 1.

2.0 OB/OD MODELING PROTOCOL

The protocol for the OB/OD modeling exercise for ARC's Orange County facility is provided in following paragraphs. The protocol describes the technical approach and parameters that were utilized when performing the computer simulations for the RTF. The criteria for evaluation of the modeling data are also discussed herein.

2.1 **Description of OB/OD Modeling Software**: The ambient air dispersion modeling analysis for ARC was performed using the OB/OD computer software program (versions 1.3.0017 dated July 2000 and 1.3.0018 dated May 2001). The U.S. Army developed this program at the Dugway Proving Grounds in Dugway, Utah. A private contractor, the H.E. Cramer Company of Sandy, Utah, was instrumental in development of the software. (The primary contact for the OB/OD model is Mr. Jay Bjorklund of the H.E. Cramer Company.)

The OB/OD model is designed for use in evaluating the potential air quality impacts of the open-air burning and detonation of obsolete munitions and solid propellants at

DOD installations and similar facilities. The model can be run using either theoretical or empirical emission factors for a variety of pollutants in either gaseous or particulate form. The software predicts the downwind transport and dispersion of these pollutants using cloud rise and dispersion model algorithms from existing EPA computer programs. The model is capable of simulating both instantaneous (i.e., detonation) and quasi-continuous (open burning/firing) events at point/volume and/or line sources. The OB/OD software program can be used to calculate time-mean concentration, dosage and particulate gravitational deposition from open burn and open detonation sources.

2.2 **Source Characteristics**: The OB/OD model was programmed to reflect actual operations at the RTF under maximum or worst-case conditions. The operating characteristics for this source are summarized below:

2.2.1 **Type of Emission Source**: The RTF was modeled as a quasi-continuous source to reflect actual rocket testing operations (i.e., open burning/firing). The effects of a one-minute test event at the maximum propellant weight of 2,000 pounds were evaluated. (The alternative modeling approach, for an instantaneous source, is appropriate for detonation events, which typically last less than 15 seconds. Detonation events are not conducted at the Orange County facility.)

In addition, the RTF was modeled as a volume (i.e., point) source (as opposed to a line source). The OB/OD model was programmed to use default settings for the dimensions of the initial source material (i.e., 10 meters by 10 meters by 10 meters). A default setting of five meters was utilized for the effective height of the initial release above ground level.

(The aforementioned settings were programmed with the direct assistance of the designer of the OB/OD software. These default values should accurately reflect actual operating conditions at the ARC facility. According to Mr. Bjorklund, the dimensional settings reflect the volume of the initial release (i.e., exhaust plume/fireball), rather than the physical size of the rocket motor being tested. One test run was performed to determine the effects of the dimensions of the initial source material and the initial release height at the RTF on the predicted air emissions. The dimensions of the source were programmed at 10 meters by 10 meters by two meters. In addition, a value of two meters was used for the effective height of the initial release above ground level. The predicted ambient air concentrations under these circumstances were not significantly different from those values resulting from the default settings described above.)

2.2.2 **Characteristics of Rocket Test Event**: The OB/OD model was programmed to simulate the firing of 2,000 pounds of solid rocket propellant per event. The effects of only one test event per day were evaluated. For modeling purposes, it was assumed that the rocket motor will fire for a one-minute period before all the fuel is consumed (based on an estimated burn rate and the site-specific quantity of propellant combusted per event). The time of the test event was arbitrarily set at 12:00 noon. (These source characteristics reflect the anticipated maximum operating conditions at the RTF. More than one rocket test event may be performed per day, but the aggregate weight of propellant fired will not exceed 2,000 pounds. Similarly, the tests may range from several seconds to ten minutes in duration, depending on the size of the rocket motor and/or the physical test conditions.)

(Two test runs were performed to determine the effects of the time of the rocket test event on the predicted air emissions. Morning and afternoon events (9:00 A.M. and 3:00 P.M., respectively) at the RTF were evaluated. The predicted ambient air concentrations of PM under these circumstances were not significantly different from those values resulting from a rocket test event occurring at 12:00 noon.)

2.2.3 **Characteristics of Rocket Propellants Tested**: An estimated burn rate of 15,500 grams per second was used for modeling purposes at the RTF. A default setting of 1,000 calories per gram was utilized for the heat content of the solid rocket fuel. (The OB/OD model contains a database of common propellants and explosives and their thermodynamic characteristics. Site-specific values for the heat content and burn rate of the propellants are not available.)

2.2.4 **PM Emission Factor**: The "super rocket propellant" emission factor for PM was utilized when conducting the OB/OD modeling runs for the RTF. This value is presented in Table 1. (This theoretical emission factor was calculated using the EQTCH software program. See Section 1.3 above for a brief discussion of the methodology used by ARC to develop this information.)

2.3 **Receptor Grid for OB/OD Model**: A rectangular (Cartesian) receptor grid was utilized during the OB/OD modeling exercise. The RTF was established at the point of origin (0.0, 0.0) for the network. The grid was extended for 10,000 meters from this source along the east-west (x) axis and north-south (y) axis. (See Figure 1 (Site Map) for details.)

The placement of the receptors was graduated. These points were placed at 100-meter intervals for the first 3,000 meters from the RTF. A spacing of 500 meters was used from 3,000 meters to 6,000 meters. Finally, the receptors were placed at 1,000-meter intervals from 7,000 meters to 10,000 meters. Flat terrain settings with ground level receptors were utilized to reflect actual on-site conditions and points of exposure at the RTF since the terrain within the vicinity of the ARC facility is relatively flat. PM concentrations were also determined at 29 "fence line" receptors situated along the ARC property boundary.

2.4 **Meteorological Data**: The meteorological data used in conjunction with the OB/OD model consisted of hourly, joint-frequency distributions of wind direction, wind speed, temperature and Pasquill atmospheric stability classes arranged in chronological order. Per the instructions of the VDEQ, the set of meteorological information used for the ARC modeling exercise consisted of the most recent five years of data available (i.e., calendar years 1987 through 1991) for Dulles Airport near the city of Herndon (Loudoun County), Virginia. (The aforementioned frequency distributions are commonly referred to as STAR (stability array) data. The meteorological data for Dulles Airport were provided by the VDEQ.)

Default values were utilized for all other meteorological variables in the OB/OD model. These settings included the following:

- Air Humidity = 50 percent
- Air Pressure = 870 millibars

The OB/OD model did not include calm hours (i.e., no wind conditions) in the dispersion calculations.

2.5 **Time-Averaging Periods**: The OB/OD software program can be used to calculate time-mean concentration, dosage and other emission values. The NAAQS for PM are based on 24-hour and annual time-averaging periods. During the OB/OD modeling exercise for the Orange County facility, the ground-level ambient air concentrations of PM were accordingly computed for these periods.

The NAAQS and time-averaging periods applicable to PM are described in Table 2.

2.6 **Criteria for Evaluation of PM Emissions**: As stated previously, the OB/OD modeling exercise was conducted, in part, to determine whether the PM emissions from the RTF would cause or contribute to a violation of the NAAQS for that pollutant. The NAAQS are specified in 40 Code of Federal Regulations, Part 50. The PM standards are based on 24-hour and annual time-averaging periods. (See Table 2.) The predicted ambient air concentrations of PM from the RTF must be below the NAAQS in order to comply with federal air quality regulations.

The 50 highest ambient air concentrations of PM were determined for both the 24-hour and the annual time-averaging periods. These maximum values might occur at either on-site or off-site receptors depending on the meteorological effects. In addition, the maximum PM concentration that occurred off-site (including the fence line) was determined for each time-averaging period.

3.0 RESULTS OF OB/OD MODELING EXERCISE

The results of the OB/OD modeling exercise for the rocket testing operations at the ARC facility in Orange County, Virginia are summarized in the following paragraphs. The data demonstrate that the predicted maximum ground-level ambient air concentrations of PM will be below the NAAQS at all off-site receptors. The modeling results for the RTF are presented in Table 3. The concentrations are reported in units of micrograms per cubic meter (ug/m3). Only the predicted maximum off-site ambient air concentrations for the entire five-year period of meteorological data (1987 through 1991) are provided below:

3.1 **Results of Modeling for Total Particulate Matter (as PM_{10})**: According to the OB/OD model, the maximum ambient air concentrations of total particulate matter at a median particle size of 10 um (PM_{10}) generated by the RTF operations will be well below both the 24-hour and annual NAAQS. The predicted ground-level concentrations and regulatory standards-are as follows:

- The maximum off-site 24-hour concentration of PM_{10} is 7.62 ug/m3, which is less than the NAAQS of 150 ug/m3.

- The maximum off-site annual concentration of PM_{10} is 0.33 ug/m3, which is less than the NAAQS of 50 ug/m3.

4.0 CONCLUSION OF PM MODELING

In conclusion, the predicted maximum ground-level ambient air concentrations of PM from the RTF operations will be below the NAAQS at all off-site receptors.

Summaries of the OB/OD modeling results for PM are attached for reference purposes. (Upon request, ARC will provide the VDEQ with a copy of the OB/OD modeling software package and computer diskettes containing all of the modeling data generated during this project.)

Table 1 - Physical Characteristics and Emission Factor for PM

Pollutant	Type of Pollutant	Molecular Weight (gram/mole)	Density (grams/cubic centimeter)	Emission Factor [A, B]	Worst-Case Propellant
Particulate Matter, Total (PM) [C, D]	Particulate	101.94	3.99	66.81	Arcadene 428F

(A). Worst-case "super propellant" emission factors were developed for a number of common rocket propellant formulations processed at Atlantic Research Corporation (ARC) facilities. Emission factors for the Rocket Test Facility (RTF) are expressed as pounds of pollutant released per 100 pounds of propellant fired (pounds/100 pounds) during performance testing of solid rocket motors.

ARC provided theoretical combustion data for the rocket fuels. This information was calculated using the "EQTCH Products of Combustion" computer software program. It utilizes programming developed by the U.S. Department of Defense.

(B). OB/OD modeling runs for the RTF were performed using the following source characteristics: 2,000 pounds of solid rocket propellant are fired per event; one rocket test event is conducted per day; the heat content of the waste propellant is 1,000 calories per gram (default value); and, the burn rate of the material is 15,500 grams per second (default value).

(C). Emissions of total particulate matter (PM) were evaluated as aluminum oxide (Al_2O_3) since molecular weight and density values are not available for PM. OB/OD emission factor for total PM was used in combination with the physical constants for Al_2O_3. (Al_2O_3 is one of the predominant particulate species generated during the rocket testing events.)

(D). Air emissions of PM were modeled using three different median particle sizes (i.e., "aerodynamic diameters"). These values were 10 micrometers (um), 100 um and 1,000 um. This approach was utilized in order to bracket the range of particle sizes generated during actual operation of the RTF. OB/OD model automatically calculated the particle-size distribution for each median diameter over a range of 20 size categories.

Table 2 - Time-Averaging Periods and Air Quality Standards

Pollutant	NAAQS (ug/m3)	
	24-Hour	Annual
Particulate Matter, Total (as PM_{10}) (A, B)	150	50

(A). Regulatory criteria for this pollutant are the National Ambient Air Quality Standards (NAAQS). These federal standards were established by the Environmental Protection Agency. Concentrations are reported in units of micrograms per cubic meter (ug/m3).

Two sets of NAAQS are applicable to total particulate matter. The standards are based on the median aerodynamic diameter of the particle size ranges. The NAAQS for PM with a mean diameter of 10 micrometers (um) (PM_{10}) are 150 ug/m3 (24-hour average) and 50 ug/m3 (annual arithmetic mean).

(B). Emissions of total particulate matter (PM) were evaluated as aluminum oxide (Al_2O_3) since molecular weight and density values are not available for PM. OB/OD emission factor for total PM was used in combination with the physical constants for Al_2O_3.

Air emissions of PM were modeled using three different median particle sizes (i.e., "aerodynamic diameters"). These values were 10 micrometers (um), 100 um and 1,000 um. This approach was utilized in order to bracket the range of particle sizes generated during actual operation of the RTF. OB/OD model automatically calculated the particle-size distribution for each median diameter over a range of 20 size categories.

Table 3 - OB/OD Modeling Results for PM Emission from the Rocket Test Facility

Pollutant	Averaging Period	Predicted Maximum Ambient Air Concentration (ug/m3) Calendar Years 1987 Through 1991 (A, B)				
		1987	1988	1989	1990	1991
Total Particulate Matter (PM) @ 10 um (C, D)	24-Hour	7.48	7.62	7.33	7.61	7.44
	Annual	0.38	0.41	0.36	0.46	0.41
Total Particulate Matter @ 100 um (C, D)	24-Hour	26.56	27.65	26.72	26.34	26.33
	Annual	0.69	0.71	0.68	0.68	0.66
Total Particulate Matter @ 1,000 um (C, D)	24-Hour	49.29	48.62	51.08	50.28	50.78
	Annual	4.92	4.16	5.06	4.93	5.72

(A). Maximum ambient air concentration of particulate matter (PM) at ground level as predicted by the OB/OD dispersion model. Concentrations are reported in units of micrograms per cubic meter (ug/m3). Modeling was performed using meteorological data for Dulles Airport for calendar years 1987 through 1991.

(B). OB/OD modeling runs for the RTF were performed using the following source characteristics: 2,000 pounds of solid rocket propellant are fired per event; one rocket test event is conducted per day; the heat content of the waste propellant is 1,000 calories per gram (default value); and, the burn rate of the material is 15,500 grams per second (default value).

(C). Emissions of total PM were evaluated as aluminum oxide (Al_2O_3) since molecular weight and density values are not available for PM. OB/OD emission factor for total PM was used in combination with the physical constants for Al_2O_3.

(D). Air emissions of PM were modeled using three different median particle sizes (i.e., "aerodynamic diameters"). These values were 10 micrometers (um), 100 um and 1,000 um. This approach was utilized in order to bracket the range of particle sizes generated during actual operation of the RTF. OB/OD model automatically calculated the particle-size distribution for each median diameter over a range of 20 size categories.

Table 4 - Comparison of the OB/OD Modeling Results for PM Emissions from the Rocket Test Facility to the NAAQS

Pollutant	Averaging Period	Predicted Maximum Concentration (ug/m3) and Year of Occurrence (A, B)	NAAQS (ug/m3) (E)	Pass or Fail	Maximum Concentration at Off-Site Receptor (ug/m3) (F)
Total Particulate Matter (PM) @ 10 um (C, D)	24-hour	7.62 (1988)	150 (as PM_{10})	Pass	7.62 (1988)
	Annual	0.46 (1990)	50 (as PM_{10})	Pass	0.33 (1990)
Total Particulate Matter @ 100 um (C, D)	24-hour	27.65 (1988)	-	-	27.65 (1988)
	Annual	0.71 (1988)	-	-	0.57 (1989)
Total Particulate Matter @ 1,000 um (C, D)	24-hour	51.08 (1989)	-	-	<36.94 (1991)
	Annual	5.72 (1991)	-	-	6.21E-2 (1989)

(A). Maximum ambient air concentration of particulate matter (PM) at ground level as predicted by the OB/OD dispersion model. Concentrations are reported in units of micrograms per cubic meter (ug/m3). Modeling was performed using meteorological data for Dulles Airport for calendar years 1987 through 1991.

(B). OB/OD modeling runs for the RTF were performed using the following source characteristics: 2,000 pounds of solid rocket propellant are fired per event; one rocket test event is conducted per day; the heat content of the waste propellant is 1,000 calories per gram (default value); and, the burn rate of the material is 15,500 grams per second (default value).

(C). Emissions of total PM were evaluated as aluminum oxide (Al_2O_3) since molecular weight and density values are not available for PM. OB/OD emission factor for total PM was used in combination with the physical constants for Al_2O_3.

(D). Air emissions of PM were modeled using three different median particle sizes (i.e., "aerodynamic diameters"). These values were 10 micrometers (um), 100 um and 1,000 um. This approach was utilized in order to bracket the range of particle sizes generated during actual operation of the RTF. OB/OD model automatically calculated the particle-size distribution for each median diameter over a range of 20 size categories.

(E). Regulatory criteria for PM are the federal National Ambient Air Quality Standards (NAAQS). Two sets of criteria are applicable to total PM. The standards are based on the median aerodynamic diameter of the particle size ranges. The NAAQS for PM with a mean diameter of 10 micrometers (um) (PM_{10}) are 150 ug/m3 (24-hour average) and 50 ug/m3 (annual arithmetic mean).

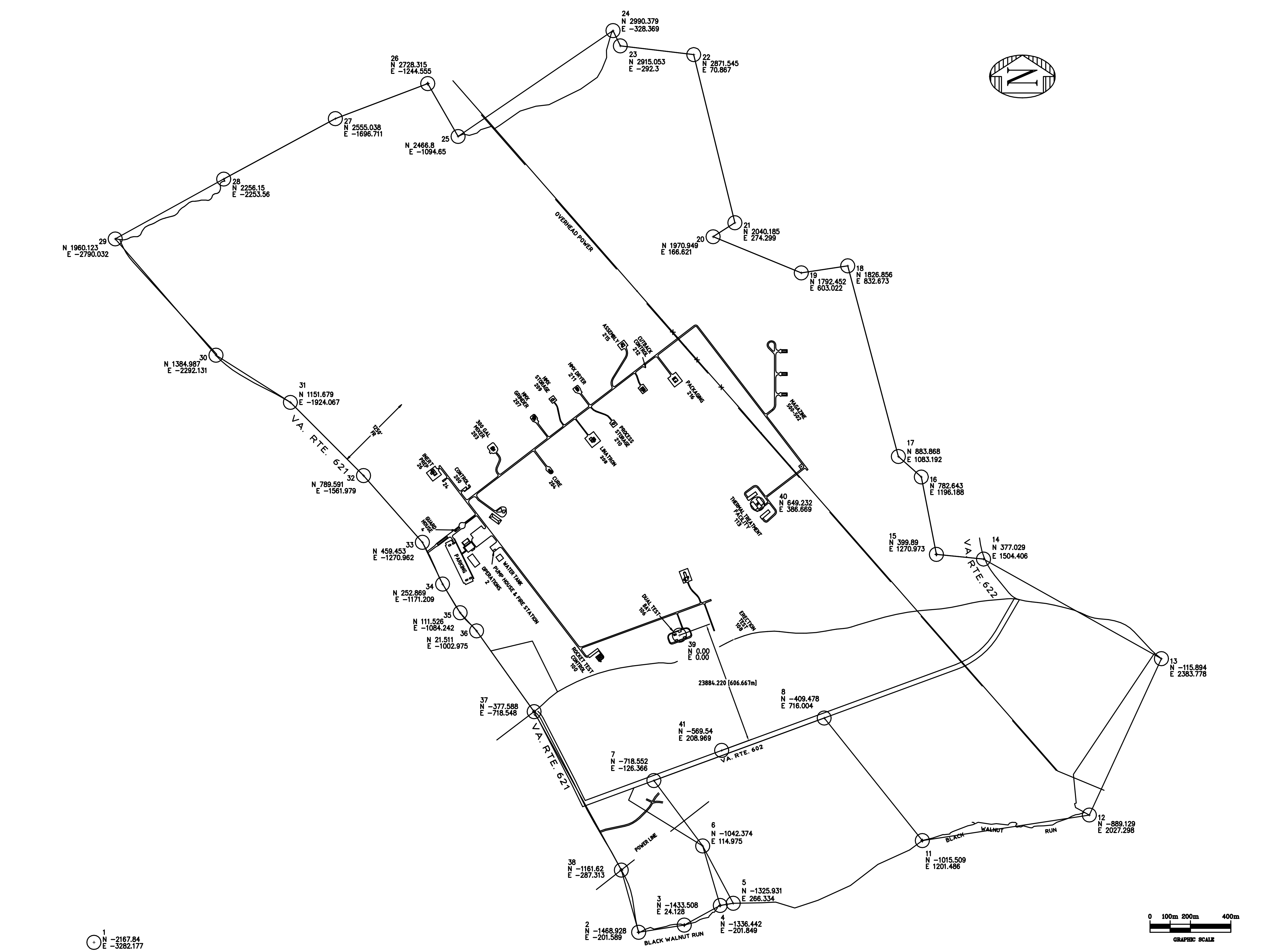
(F). Maximum off-site concentrations are also reported. Locations of the receptors where these concentrations occurred varied depending on the pollutant and time-averaging period. (The test site was established as point of origin (0.0, 0.0) for receptor grid. See attached Figure 1 (Site Map / Plot Plan) for layout and boundaries of Orange County facility.)

Figure 1

Site Map

Atlantic Research Corporation

Orange County Facility



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Orange County Facility

a subsidiary of Sequa Corporation

FILE: ARC-VA1

ORANGE COUNTY FACILITY
GENERAL SITE PLAN II

PROJECT NO.	SCALE	DRAWING NO.	REV.
3026-	AS NOTED	ARC-VA - 100-01-002	C

AEROJET

7499 Pine Stake Road
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Response to EPA Comments

EPA Region III has reviewed the air dispersion modeling data submitted by Aerojet to the DEQ on April 20, 2005. The EPA has some technical comments on the modeling studies for the Orange County facility. Aerojet's responses to the EPA's comments (as provided to Aerojet by DEQ) are addressed below:

(1). Comment: The OB/OD Model was used to estimate the PM emissions from the rocket motor testing operations. This software program is not an EPA-approved model.

Response: Aerojet acknowledges that the OBOD Model is not an EPA-approved software program. However, it is the only dispersion model designed for use in evaluating the potential air quality impacts of the firing of solid rocket propellants. It has become the industry standard, and is generally recognized by the EPA as the appropriate model for simulating propellant combustion for regulatory applications. The OB/OD program meets the EPA's Guidelines on Air Quality Models (40 Code of Federal Regulations, Part 51, Appendix W).

(2). Comment: The modeling was not run at standard air pressure of 1,013 mb. Instead, a very low pressure of 870 mb was used. Also, a relative humidity of 50% was utilized. This value might not be representative of the site conditions.

Response: The air pressure and relative humidity settings used in the OB/OD model studies were default values.

As part of this response to comments, Aerojet conducted several preliminary OB/OD modeling test runs to evaluate the sensitivity of changes in the air pressure and relatively humidity settings on the predicted ambient air concentrations of PM. The results of the test runs are summarized herein in Table #1. The use of standard atmospheric pressure (1,013 mb) rather than the default value (870 mb) increased the PM modeling results between 6% and 14%, depending on the time averaging period. A change in the relative humidity from 50% (default value) to a more representative value (75%) had no appreciable effect on the PM modeling results. (Refer to the response to Comments #3 for the overall impact of changes in the pressure and humidity values and accounting for PM background concentrations, followed by comparison to the applicable NAAQS.)

In order to address any potential regulatory concerns, updated OB/OD modeling for the Orange County facility was performed for the rocket testing operations using standard atmospheric pressure (1,103 mb) and a more appropriate relative humidity value (75%). The modeling results are provided in Table #2. (The OB/OD modeling was otherwise performed in accordance with the 2002 modeling protocol submitted to DEQ as part of the aforementioned April 2005 data package.)

(3). Comment: Background concentrations of PM were not accounted for in the OB/OD modeling studies.

Response: The DEQ provided Aerojet with background concentrations for PM_{10} that are representative of the ambient air at the Orange County facility. These values were added to the updated OB/OD modeling results to determine the total PM concentrations. The data are presented herein in Table #3.

The total ambient air concentrations of PM_{10}, including the background PM, from the rocket motor testing activities are less that the applicable National Ambient Air Quality Standards (NAAQS). Therefore, the rocket motor testing operations will not cause or contribute to any exceedance of these Standards.

Table #1 – Preliminary Comparison of Changes in Predicted Ambient Air Concentrations of PM_{10} Due To Adjustments in Air Pressure and Relative Humidity Settings [(A-D)]

	Baseline	Test 1	Test 2	Test 3
Pressure (millibars)	870	870	1,013	1,013
Humidity (%)	50	75	50	75
1-Hour Average PM_{10} (ug/m^3)	175.38	175.38	200.28	200.28
Relative Change (%)	-	±0.0	+14.20	+14.20
24-Hour Average PM_{10} (ug/m^3)	7.31	7.31	8.35	8.35
Relative Change (%)	-	±0.0	+14.23	+14.23
Annual Average PM_{10} (ug/m^3)	0.4845	0.4840	0.5132	0.5124
Relative Change (%)	-	-0.11	+5.93	+5.76

(A). Maximum ambient air concentration of particulate matter (as PM_{10}) at ground level as predicted by the Open Burn/Open Detonation (OB/OD) dispersion model. Concentrations are reported in units of micrograms per cubic meter (ug/m^3). Modeling was conducted using meteorological data for Dulles Airport for calendar years 1987 through 1991.

(B). OB/OD modeling runs for the Rocket Test Facility (RTF) were performed using the following source characteristics: 2,000 pounds of solid rocket propellant are fired per event; one rocket test event is conducted per day; the heat content of the waste propellant is 1,000 calories per gram (default value); and, the burn rate of the material is 15,500 grams per second (default value).

(C). A site-specific OB/OD emission factor for PM_{10} was used. The molecular weight and density values for aluminum oxide (Al_2O_3) were utilized since physical constants are not available for total PM.

(D). The OB/OD model automatically calculated the particle-size distribution for PM_{10} over a range of 20 size categories.

Table #2 – Updated Air Dispersion Modeling Results for PM_{10} Emissions from Rocket Test Operations at Orange County Facility

Pollutant [C, D]	Averaging Period	Predicted Maximum Ambient Air Concentration (ug/m^3) Calendar Years 1987 Through 1991 [A, B]				
		1987	1988	1989	1990	1991
PM_{10}	24-Hour	8.36	8.37	8.35	8.35	8.37
	Annual	0.37	0.43	0.44	0.52	0.45

(A). Maximum ambient air concentration of particulate matter (as PM_{10}) at ground level as predicted by the Open Burn/Open Detonation (OB/OD) dispersion model. Concentrations are reported in units of micrograms per cubic meter (ug/m^3). Modeling was conducted using meteorological data for Dulles Airport for calendar years 1987 through 1991.

(B). OB/OD modeling runs for the Rocket Test Facility (RTF) were performed using the following source characteristics: 2,000 pounds of solid rocket propellant are fired per event; one rocket test event is conducted per day; the heat content of the waste propellant is 1,000 calories per gram (default value); and, the burn rate of the material is 15,500 grams per second (default value).

(C). A site-specific OB/OD emission factor for PM_{10} was used. The molecular weight and density values for aluminum oxide (Al_2O_3) were utilized since physical constants are not available for total PM.

(D). The OB/OD model automatically calculated the particle-size distribution for PM_{10} over a range of 20 size categories.

Table #3 - Comparison of Updated Air Dispersion Modeling Results for PM_{10} Emissions from Rocket Test Operations to the NAAQS

Averaging Period	PM_{10} Concentration (in ug/m^3) (A-D)				Pass or Fail (I)
	Emissions from RTF (E)	Background Value (F)	Total PM (G)	NAAQS (H)	
24-hour	8.37	43	51.37	150	Pass
Annual	0.52	17	17.52	50	Pass

(A). Open Burn/Open Detonation (OB/OD) modeling was conducted using meteorological data for Dulles Airport for calendar years 1987 through 1991. Concentrations are reported in micrograms per cubic meter (ug/m^3).

(B). OB/OD modeling runs for the Rocket Test Facility (RTF) were performed using the following source characteristics: 2,000 pounds of solid rocket propellant are fired per event; one rocket test event is conducted per day; the heat content of the waste propellant is 1,000 calories per gram (default value); and, the burn rate of the material is 15,500 grams per second (default value).

(C). A site-specific OB/OD emission factor for PM_{10} was used. The molecular weight and density values for aluminum oxide (Al_2O_3) were utilized since physical constants are not available for total PM.

(D). The OB/OD model automatically calculated the particle-size distribution for PM_{10} over a range of 20 size categories.

(E). Maximum ambient air concentration of particulate matter (as PM_{10}) at ground level as predicted by the OB/OD dispersion model. The maximum 24-hour average concentration will occur in calendar year 1988, whereas maximum annual average concentration will occur in 1990.

(F). Background concentrations of PM_{10} in ambient air. The Virginia Department of Environmental Quality provided the appropriate data.

(G). Total ambient air concentration of PM_{10} is equal to sum of the RTF emissions plus the background value.

(H). The regulatory criteria for PM are the federal National Ambient Air Quality Standards (NAAQS). The NAAQS for PM_{10} are 150 ug/m^3 (24-hour average) and 50 ug/m^3 (annual arithmetic mean).

(I). If the predicted total concentration is *less than* the applicable NAAQS, then the emissions are acceptable from an air quality standpoint.

Inventory of Enclosed Documents

Technical documentation in support of the Opacity Variance for the rocket motor testing operations at the Orange County facility are listed below and are available in electronic form:

(1). Edited Output Files for Updated OB/OD Modeling Runs for PM for Calendar Years 1987 Through 1991

(2). Input and Output Files for All Updated OB/OD Modeling Runs for PM (Four Files Per Run)

(3). Edited Output Files for OB/OD Modeling Test Runs for Pressure and Humidity

(4). Input and Output Files for All for OB/OD Modeling Test Runs for Pressure and Humidity (Four Files Per Run)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

JUL 24 2008

Mr. Michael G. Dowd, Director
Air Division
Virginia Department of Environmental Quality
P.O. Box 1105
Richmond, Virginia 23218

Dear Mr. Dowd:

This is in response to your May 5, 2008 letter requesting concurrence with the Virginia Department of Environmental Quality's (VADEQ) decision to allow the use of the Open Burn/Open Detonation (OB/OD) dispersion model (version 01.3.0021) for an air quality analysis of a request submitted by Aerojet Corporation for a variance from Virginia's standard for visible emissions, 9 VAC 5-50-80. The applicant, Aerojet Corporation, used the OB/OD model for its facility located in Orange County, Virginia to support its request for this opacity variance for its rocket motor test operations conducted at the facility. The OB/OD model was used by Aerojet Corporation to demonstrate protection of the national ambient air quality standards (NAAQS) in its variance request to the VADEQ.

The U.S. Environmental Protection Agency (EPA) Control Strategy regulations of 40 CFR 51.112 require that air quality modeling be based on the preferred models identified in Appendix W to 40 CFR Part 51, otherwise known as the Guideline on Air Quality Models (GAQM), except where the preferred model is inappropriate. The GAQM further specifies the conditions and procedures for selecting an alternative model. In the November 9, 2005 Final Rule which revised the GAQM, EPA established the American Meteorological Society (AMS)/EPA Regulatory Model (AERMOD) dispersion model as the preferred model for flat and complex terrain. As you noted in your letter, the OB/OD model is designed for use in evaluating the potential air quality impacts of the open-air burning and detonation of obsolete munitions and solid propellants at Department of Defense (DOD) installations and similar facilities.

EPA has reviewed your rationale for allowing Aeroject Corporation to use the OB/OD model for the air quality analyses for the Aerojet facility in Orange County. The detailed discussion of the criteria under section 3.2.2(e) of the GAQM contained in your letter fulfills the criteria for selecting OB/OD as an alternative to the generally preferred AERMOD model. Therefore, EPA approves and concurs with the use of the OB/OD modeling system for this application.

Please recognize that EPA believes that a case-by-case approval for using OB/OD as a basis for a regulatory action also obligates you to give public notice and to provide the opportunity for a public hearing on the use of this alternative to the generally preferred model. EPA acknowledges that VADEQ has fulfilled the public notification requirements of this approval; a copy of an April 1, 2008 "Certification of Public Participation Activities" notice for the use of an alternative model was included with VADEQ's May 5, 2008 request.

If you have any questions about this approval, please contact Mrs. LaRonda Koffi, EPA's Virginia Liaison, at 215-814-5374 or Mr. Walter K. Wilkie of the Air Protection Division at 215-814-2150.

Sincerely,

Donald S. Welsh

Donald S. Welsh
Regional Administrator